Beta-Neutrino Correlation in Laser Trapped ^{21}Na

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The beta decay rate for an unpolarized nucleus is $\Gamma \propto 1 + a\left(\vec{p}_e \cdot \vec{p}_\nu / E_e E_\nu\right)$, where $\vec{p}_e$ and $\vec{p}_\nu$ are the beta and neutrino momenta [1]. The neutrino momentum cannot be directly measured, but it can be inferred from the momentum of the recoil nucleus. In the Standard Model, the beta-neutrino correlation, *a*, is calculated to be 0.558(3) for the decay ^{21}Na-->^{21}Ne+β^++ν [2]. A precise measurement of *a* can limit the existence of scalar or tensor currents from higher mass weak bosons present in some extensions to the Standard Model. We have made a preliminary measurement of the beta-neutrino correlation coefficient *a* using a laser trap as an isotopically pure, localized source of ^{21}Na.

We produce ^{21}Na ($T_{1/2}$ = 22.5 s) on-line at the 88" Cyclotron by bombarding a heated magnesium oxide target with 2 μA of 25 MeV protons. Passive and active laser collimation increases the forward flux of the resulting hot, neutral ^{21}Na beam towards our laser trap. The ^{21}Na is slowed and trapped with a combination of laser and magnetic fields and brought nearly to rest in a small (FWHM < 1 mm) trap located between the beta and recoil ion detectors.

Several changes were made to the optical setup throughout the year, most notably a more spatially uniform slowdown laser beam with a dark spot. These changes greatly increased the flux of slowed atoms and up to 500,000 atoms were maintained in the trap – a factor of 10 improvement over the previous year. In addition, we increased the event rate by replacing the microsphere plate detector with a microchannel plate detector that has a greater detection efficiency for multi-keV recoil ions.

When the ^{21}Na decays, we detect coincident beta-ion events that fall within a 3 μs timing window after the initial beta trigger. The beta-neutrino correlation is determined by the time of flight spectrum of the daughter ^{21}Ne ions in the presence of a drift electric field. This spectrum is fit to a sum of two independent template curves (one of which proportional to *a*) generated by Monte-Carlo simulation of the flight path of ^{21}Ne ions in the numerically calculated electric field for our geometry.

We reduced the statistical uncertainty on *a* to <1% during 15 hours of acquisition time. The branching ratios of the first four charge states of ^{21}Ne following beta decay have been determined and limits placed on the higher charge state branching ratios. Figure 1 shows background subtracted atom trapping data with a fit to the data. Our preliminary analysis gives a value of *a*=0.546(34) which is consistent with the Standard Model calculation. This uncertainty is dominated by coincident events in which positrons from the trap scatter off the vacuum chamber walls and trigger the beta detector. This effect is difficult to simulate and leads to the ~5% uncertainty in the measurement. All other systematic uncertainties have been estimated to be less than 2%. We are currently designing a more sophisticated beta detector (ΔE-E telescope) with a collimator to reduce the uncertainty due to scattering to less than 1%.

Footnotes and References

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1. J.D. Jackson, S.B. Treiman, and H.W. Wyld, Phys. Rev. **106**, 517 (1957).

2. O. Naviliat-Cuncic, *et al.*, J. Phys. G **17**, 919 (1991).

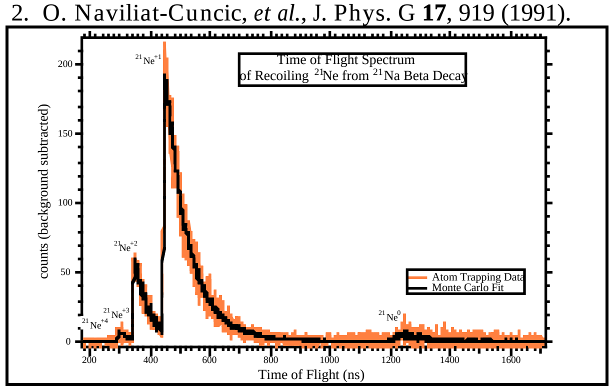

Figure 1. Approximately 1/10th of the data set.